Journal of Forensic and Legal Medicine 19 (2012) 316–320

Contents lists available at SciVerse ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/locate/jflm

Original communication

Estimation of length of humerus from its fragmentary portions

Sachidananda Mohanty MD, LL.B, Professor & Head *, Geeta Sahu MD, Assistant Professor, Sudeepa Das MD, Assistant Professor

Department of Forensic Medicine and Toxicology, Post Graduate Institute of Forensic Medicine and Toxicology, M.K.C.G. Medical College, Berhampur, Odisha 760004, India

ARTICLE INFO

Article history:
Received 4 December 2010
Received in revised form
28 November 2011
Accepted 13 February 2012
Available online 8 March 2012

Keywords:
Humerus
Fragment
Regression equation

ABSTRACT

The objective of the present study was to estimate the length of humeri from measurements of their fragments in south Indian population. This is important in forensic investigations and in archaeological studies particularly when the fragmentary portions are examined. For this purpose 200 adult humeri, 100 each of either sex in dried and fully ossified condition were taken for study. Each of the humerus bone was fragmented into five fragments by drawing imaginary lines with reference to their specific anatomical landmarks. The fragments are H2 (a–b), H3 (b–c), H4 (c–d), H5 (d–e) and H6 (e–f). After applying necessary statistical analysis a definite mathematical correlation in forms of proportion and regression equation was established between each fragment to the total length of humerus (H1).

All the formulae thus derived for each of the fragments of bones are not only significant but also possess a high degree of prediction. Among all the fragments, the longest fragmentary portion i.e.H4 (c–d) predicts the highest percentage of accuracy ($H1 = 166 + 0.712$ H4 M, $H1 = 90.2 + 1.06$ H4F) followed by H2 (a–b) in calculating the total length of humerus ($H1 = 307 + 0.330$ H2M, $H1 = 243 + 1.73$ H2F). In conclusion, our study demonstrated that length of the humerus can be estimated from measures of different fragments.

1. Introduction

Identification of an unknown dead body is one of the important works of a forensic expert. Many factors are essential to establish the identity of an unknown dead body, stature is one of them. Efforts are on since the inception of Forensic anthropology to predict the stature from the length of long bones.

Since then anthropometric techniques are being used to estimate stature from bone length and unknown body parts by different anthropologists, medical scientists and anatomists.[1–3] Stewart[4] and Krogman and Iscan[5] have considered stature as a parameter of human biodemography. Working on this Steele[6] established a correlation between limb bone length and stature. Subsequently in 19th century Pearson[3] and in 20th century Trotter[7–9] pioneered the estimation of stature from lengths of long limb bones. Later on many authoritative works was carried out on different population at different areas by different workers on stature and were successful in estimating stature from length of long limb bones.

It is difficult to calculate stature from limb bones but it still becomes more difficult to estimate the stature form fragments of bones, available following mass disasters or even blast injuries. It is also seen very often fragments of bones are neglected by most of the forensic anthropologists assuming that no relevant information can be obtained from such fragments.

An answer to this problem was suggested long back in 1935 by Muller,[10] who provided scientific basis for the estimation of length of bone through the fragments.

Subsequently Steele and Mckern[11] realised the value of Muller's technique in estimating total length of bone from broken/fragmentary bones and employed the least square method of factor analysis to formulate sex specific regression equation for each segment. A year later, Steele[6] in 1970 used these segment lengths for direct estimation of stature thereby reducing the standard deviation and established sex and race specific standards for American whites and blacks.

Steele's method was revised later on by Simmons et al.[12] in 1990 to calculate the stature from fragmentary femuri through linear and transverse measurements since then researchers world over including some Indian forensic pathologists like Chandra et al.[13]

* Corresponding author. Tel.: + 91 680 2292533; +91 6802292261; + 91 94372 60015 (mobile); fax: +91 6802292809.
E-mail address: sachimohanty@rediffmail.com (S. Mohanty).

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doi:10.1016/j.jflm.2012.02.004

and Mysorekar et al.[14–16] used these methods on different upper and lower limb bones and formulated regression equation for estimation of different bone lengths. Akman[17] while studying on the Turkish population also divided the humerus into five fragments and estimated the length of humerus. Chandra and Nath[18,19] on the other hand used a single transverse dimension of humerus and femur to compute a multification factor (MF) for the reconstruction of bone length. Rao et al.[20] in 1989 used linear segment lengths of upper extremity bones to reconstruct their respective lengths following Muller's method. Badkur and Nath[21] used a set of linear, transverse, saggital and circumferential dimensions of humerus and Ulna to formulate linear as well as multilinear regression equation for estimation of bone length. Gupta and Nath[22] and Udhaya et al.[23] in India used linear segment lengths of all major limb bones including humerus to reconstruct respective bone length from their fragmentary measurements.

Considering the causal relationship between the fragment and the total length of bone and inadequacy of this type of work involving this locality, an attempt in this present study has been made to formulate the sex specific proportion and linear regression formulae for the estimation of humeral length using a total of five fragmentary measurements.

2. Material and methods

The study was undertaken retrospectively over a period of 2 years in the Department of Forensic Medicine and Toxicology, M.K.C.G. Medical College, Berhampur, India from January 2008 to December 2009, with help and support from the Department of Anatomy.

Two hundred pieces of adult humeri, 100 each of either sex in dried and fully ossified state, taken from the collection of bones of the Department of Forensic Medicine and the Department of Anatomy for study. The Pathological bones were not included in the study. The sexing of bones to males and females were done by considering the general sexual differences and the biometric measurements. In the present study because of the unavailability of information about the individuals, their exact age, socioeconomic status and height of the person it was not possible to establish correlations between the measurements of the fragments of the humerus and the height of each person, rather correlation was established between length of humerus and its fragments. It is assumed that the bones were of ethnic Indians of adult age mostly belonging to the State of Odisha, present at the southern part of India.

All the measurements were made on the same osteometric board. Each humerus bone was positioned in such a manner that the highest point of the head was in contact with the fixed arm and the vertical wall of the board, the longitudinal axis of the bone being parallel to the longitudinal axis of the board. The movable arm was then brought into firm contact with the deepest point of the trochlea and the length of the bone read of the scale to nearest millimeter. A set-square with one edge parallel to the scale was then moved down, so that it touched the different anatomical landmarks and accordingly the fragments were measured. Five fragmentary portions were made of each humerus bone by allocating different anatomical landmarks, the details of which are given below in Fig. 1.

a – a is the most proximal point on the head;
b – b is the distal point of circumference of the head;
c – c is at the convergence of two areas of muscle attachment just below the major tubercle;
d – d is at the upper margin of the olecranon fossa;
e – e is at the lower margin of the olecranon fossa; and
f – f is at the most distal point on the trochlea.

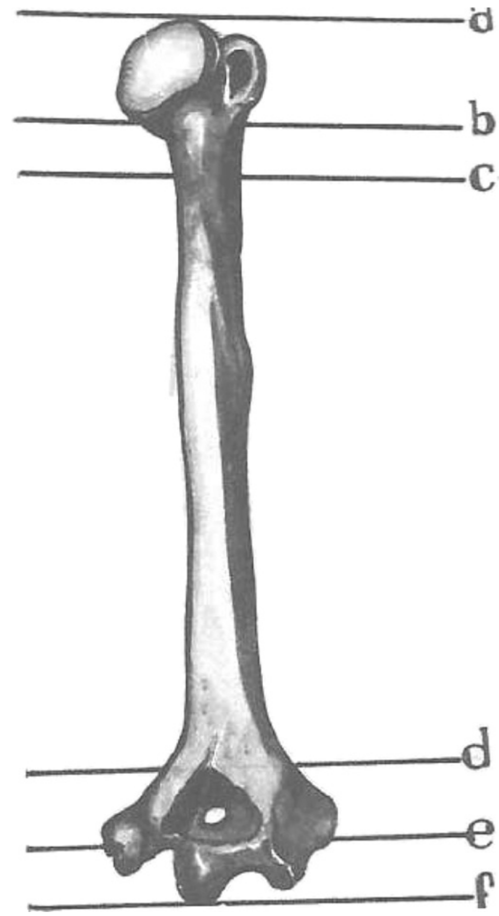

Fig. 1. Humerus in relation to different fragments.

The fragments are:

a–f = total length termed as H1
a–b = H2
b–c = H3
c–d = H4
d–e = H5
e–f = H6

3. Statistical analysis

The various measurements were analyzed by statistical package, of a computer. The regression equations were derived to correlate the different fragments to the total length of humerus. Amongst the several parameters the significant parameters like *t*-ratio, corr-coef and *p*-value were given due importance while calculating the length of humeri.

All the statistical calculations and comparisons have been carried out at 5% level of significance i.e. $P = 0.05$.

4. Results

Two hundred samples of humerus, 100 each of male and female bones were studied. Each humerus was divided into five fragments by taking into consideration of certain anatomical landmarks. In male the length of humerus varies from 312 mm to 334 mm with a mean of 317.98 ± 3.9 mm, while in females the length varies from 276 mm to 311 mm with a mean of 301.06 ± 4.49 mm. All the

fragments of humerus irrespective of sex bear a positive correlation with the total length i.e. H1 (a–f). The first fragment H2 (a–b) constitute 10.9% (34.67 mm) by proportion of total length in male and almost equal percentage of proportion to the total length in female 11% (33.35 mm). The regression equation to calculate the total length from H2 is $H1 = 307 + 0.330H2$ and $H1 = 243 + 1.73H2$ for male and female respectively. The next fragment H3 (b–c) constitute about 10.5% (33.54 mm in male & 31.84 mm in female) of proportion to the total length of the bone in both the sexes and yields better result with minimal error to calculate the stature through regression equation and the obtained regression equation to calculate the total length from H3 is $H1 = 271 + 0.139H3$ and $H1 = 243 + 1.82H3$ for male and female respectively. The third fragment H4 (c–d) is the longest segment and constitute 67.06 % (213.25 mm) by proportion to the total length in male and in female it constitute 66.3% (199.83 mm) of the total length. The regression equation to calculate the total length from H4 is $H1 = 166 + 0.712H4$ and $H1 = 90.2 + 1.06H4$ for male and female respectively. This segment yield very good result and has got very close proximity to the total length of bone. The last two fragments i.e. H5 (d–e) constitute about 5.1 % (16.24 mm) in male and 5.6 % (17.02 mm) in female by proportion to the total length respectively where as the last fragment H6 (e–f) constitute 6.4% (20.26 mm) and 6.3% (19.25 mm) by proportion to the total length of humerus respectively to male and female. Although these two segments yield good result in calculating the stature but not up to the satisfaction, in comparison to other segments. The regression equation to calculate the total length from H5 is $H1 = 309 + 0.559H5$ and $H1 = 276 + 1.45H5$ for male and female respectively, while the regression equation to calculate the total length from H6 is $H1 = 284 + 1.67H6$ for male and $H1 = 261 + 2.10H6$ for female.

5. Discussion

Living stature prediction, from lengths of the limb bones, is one of the oldest problems in the history of anthropology. Estimation of stature from the measurements of long bones plays a major role in anthropological and medico-legal study. In the archaeological approach, statures which are estimated from human skeletal remains is an essential step in assessing health, sexual dimorphism and the general body size that trends among the past populations.[25] In addition to archaeology the height of individuals is also equally important for medico-legal investigations. Thus, in forensic anthropology and in medico-legal investigations, projection of stature from the bones plays an important role in the identification of missing persons.[26]

The estimation of living stature can be done from the humeral length in the absence of more appropriate long bones as the femur or the tibia.[11] In connection with these Williams et al.[24] stated that the humerus is the longest and the largest bone of the upper limb and it is very important to identify the humeral length from the segmental measurements. In addition to all this, it is also said that in forensic investigations and anthropometric studies, the mean value of the total humerus length gives important evidence to indicate the characteristic features of a population.[1–3]

In the present study mean humeral length is 31.78 ± 0.3 cm for male and 30.14 ± 0.45 cm for female (Table 2). Studies at Turkey[17] revealed the mean humeral length to be 30.71 ± 2.08 cm, studies at Brazil by Salles et al.[29] revealed the mean humeral length to be 31.3 ± 2.3 cm (right) and 30.5 ± 1.5 cm (left) respectively. A recent study undertaken by Udaya et al.[23] in Southern India revealed the mean humeral length to be 30.28 ± 2.444 cm (right) and 29.944 ± 2.019 cm (left). In all these studies as narrated above the mean humeral length lies between 30 and 31 cm with SD, showing minimal variation in length. We consider that these discrepancies could be the result of factors such as age, sex, race, and also environmental factors affecting bone growth, such as nutrition, physical development and genetic factors.

Krogman and Iscan[5] while delineating the different studies carried out by eminent scholars world over on stature estimation from long bones, commented that the broken or burnt bone fragments recovered from the crime scene, air crash or train mishap should be measured and subjected to estimation of respective bone length at the first opportunity. Stature can be estimated subsequently by employing stature formulae for the concerned bone to the bone length estimates. The initial part of their suggestion was neglected by most researchers. As a result only a few studies are available on different long bones including humerus.

In our study we have taken the views of those workers who studied only on the humeral fragments to estimate the length. On this aspect Muller,[10] Steele and McKern,[11] Gupta and Nath,[21] Mysorekar et al.,[15] Rao et al.,[20] Akman et al.,[17] Salles et al.[29] and Udhaya[23] used linear segment lengths for estimation of bone length and stature. In due course while studying on humerus Chandra and Nath[18,19] used a single transverse measurement to estimate bone length through multiplication factors and Badkur and Nath[22] used multiple dimension like linear, transverse, saggital and circumferential dimensions to estimate both length as well as stature.

In the present study, we followed Muller's technique and succeeded in deriving proportional length of fragments sex wise. Muller[10] in his study undertook humerus from general population as a whole without taking sexual variation into consideration and fragmented humerus into five fragments by taking specific anatomical landmarks and brought out proportional relationship with the total length of humerus. On comparison the proportion of fragments in our study almost tallies with the proportional measurements suggested by Muller[10] with slight variation (Table 1). Besides Muller[10] and Akman et al.[17] while working on Turkish population are the only authors among all listed, fragmented humerus to 5 at par with our study. H3 and H4, the last 2 fragments of Akman's appears to be taken by same anatomical

Table 1
Proportional comparison of fragments.

Fragments	Muller's data (1935)	Present data (2009)	
		Male	Female
a–f (total length-H1)	100%	100%	100%
a–b (H2)	11.44% + 1.71%	10.9% ± 1.13%	11% ± 1.36%
b-c (H3)	7.60% + 1.67%	10.5% ± 1.46%	10.5% ± 1.55%
c-d (H4)	69.62% + 1.74%	67.06% ± 2.62%	66.3% ± 2.56%
d–e (H5)	6.26% + 0.90%	5.1% ± 1.61%	5.6% ± 1.00%
e–f (H6)	5.47% + 0.86%	6.4% ± 1.33%	6.3% ± 1.21%

Table 2
Morphometric measurements of humerus.

Measurement	Male/female	Mean ± SD (mm)	Proportion in %
H1	Male	317.98 ± 3.9	100
	Female	301.06 ± 4.49	100
H2	Male	34.67 ± 1.13	10.9
	Female	33.35 ± 1.36	11
H3	Male	33.54 ± 1.46	10.5
	Female	31.84 ± 1.55	10.5
H4	Male	213.25 ± 2.62	67.06
	Female	199.83 ± 2.56	66.3
H5	Male	16.24 ± 1.61	5.1
	Female	17.02 ± 1.00	5.6
H6	Male	20.26 ± 1.33	6.4
	Female	19.25 ± 1.21	6.3

Table 3
Significant statistical variables for humerus.

Fragments	Male/female	Corr-coef	*T*-ratio	*P*-value	Regression equation $y = a + bx$
a–f = H1	Total length of bone				
a–b, H2	Male	0.097	0.96	0.339	H1 = 307 + 0.330H2
	Female	0.526	6.13	0.000	H1 = 243 + 1.73H2
b–c, H3	Male	0.524	6.09	0.000	H1 = 271 + 0.139H3
	Female	0.631	8.06	0.000	H1 = 243 + 1.82H3
c–d, H4	Male	0.479	5.40	0.000	H1 = 166 + 0.712H4
	Female	0.602	7.46	0.000	H1 = 90.2 + 1.06H4
d–e, H5	Male	0.232	2.36	0.020	H1 = 309 + 0.559H5
	Female	0.324	3.39	0.001	H1 = 276 + 1.45H5
e–f, H6	Male	0.575	6.95	0.000	H1 = 284 + 1.67H6
	Female	0.569	6.86	0.000	H1 = 261 + 2.10H6

landmark as our study measures 24.2 ± 2 (Rt), 23.9 ± 2.6 (Lt) and 40.6 ± 3.3 (Rt), 39.7 ± 3.4 (Lt) respectively in comparison to 16.24(H5M), 17.02 (H5F) and 20.26(H6M), 19.25(H6F) of our study respectively when the total mean humeral length almost remain same in either case. We feel these diversities could be due to differences in the specific anatomical reference points which are taken as criteria in the measurements in addition to the causes cited already.

On further analysis, we formulated Regression equation for each fragment sex wise to estimate the length of humerus which yields good result (Table 3). Krogman[5] stated that Regression analysis is a more appropriate method for defining the relationship between the length of the long bones and the living height of the individuals and between the length of measurements of the long bone fragments and their maximum length. The systematic use of regression formulae derived in a specific population can under or overestimate stature, when applied in another population.[27,28] Thus authors have recommended that regression equations which are obtained in a certain population should not be applied to other populations.[30,31] In our study, the data was sex aggregated. Therefore we feel that the regression equation so derived separately for each fragment sex wise appears to be more advantageous as stated by Iscan[32] than the work of Muller and can be suited best to estimate the length of humerus of this locality.

6. Conclusion

Knowledge of the morphometric values of humerus segments are important in Forensic, Anatomic and Archaeological cases in order to identify unknown bodies, their origin and stature. At times it is also helpful for the clinicians in the treatment of the humeral fractures affecting different segments.

Our study supplies the mean values of the different morphometric measurements from the humerus, as a result of which these measurements may help to indicate the characteristic morphological features of humerus segments in our south Indian population. It also predicts that there exists a definite relationship between each fragment and the total length of humerus bone of either sex in terms of proportion and regression equation. The greater is the length of fragment, better is the result. The regression equation so derived for each fragment can be utilized for the estimation of total length of humerus and simultaneously the stature of the individual by using the conventional formulae with much accuracy.

Our results lead us to conclude that the proportion and regression equation evolved in relation to each fragment of humerus can throw more light in solving the medico-legal problem involving stature of this locality and also help archaeologists, anatomists a lot in their endeavour.

At the end it is suggested that stature should be estimated using the conventional method, i.e. from intact bones. However in case of non-availability of intact bone this method can be used for reliable estimation of bone length and stature. A further study of large number of long bones besides humerus, sex wise is required.

Ethical approval
The research was carried out on dried and ossified bones and as such the institutional ethical committee approval was taken prior to starting of the work.

Funding
None declared.

Conflict of interest
None declared.

Acknowledgement

We are extremely thankful to Dr. Kiran Kumar Patnaik and Dr. Abarnita Sethi for their help, valuable guidance in preparation of this manuscript.

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